Thermal Testing Short Course

Types of Thermal Testing

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There Are Three General Categories

DEVELOPMENTAL TESTING	ASSEMBLY PROTOFLIGHT/ QUALIFICATION OR FLIGHT ACCEPTANCE	SYSTEM- OR ASSEMBLY-LEVEL THERMAL BALANCE
• To characterize parameters that are difficult to quantify analytically • To characterize design performance/behavior	• To demonstrate in-specification hardware performance beyond allowable flight temperature range • To uncover design or workmanship defects	• To validate a thermal design • Empirical validation is the goal • To demonstrate functionality at expected temperatures
• Thermal environment is known • Temperature is a dependent parameter	• Temperature is an independent parameter; specified *a priori* along with dwell times, ramp rate, & number of cycles	• Thermal environment is known • Temperature is a dependent parameter

Thermal Development Testing

- **Used to assist design development, especially for situations that are difficult to characterize analytically & are key thermal design drivers**
  - **Insulation performance, especially MLI blankets**
  - **Interface contact conductance**
  - **Bearing conductance**

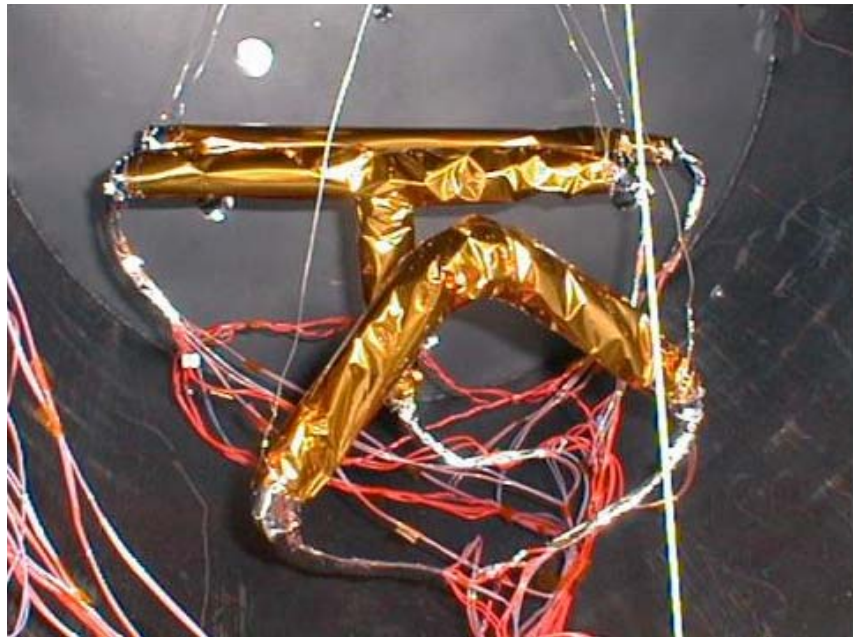
- **Used to expand thermal design space beyond a "single point"**
  - **Investigate if a design approach is feasible ("proof-of-concept")**
  - **Determine design sensitivity to key thermal parameters**

- **This type of testing aims to reduce design deficiency risk**

- **Typically, non-flight hardware used for test article**
  - **You must understand your needs for the fidelity of the test article (thermal control model or thermal mock-up)**

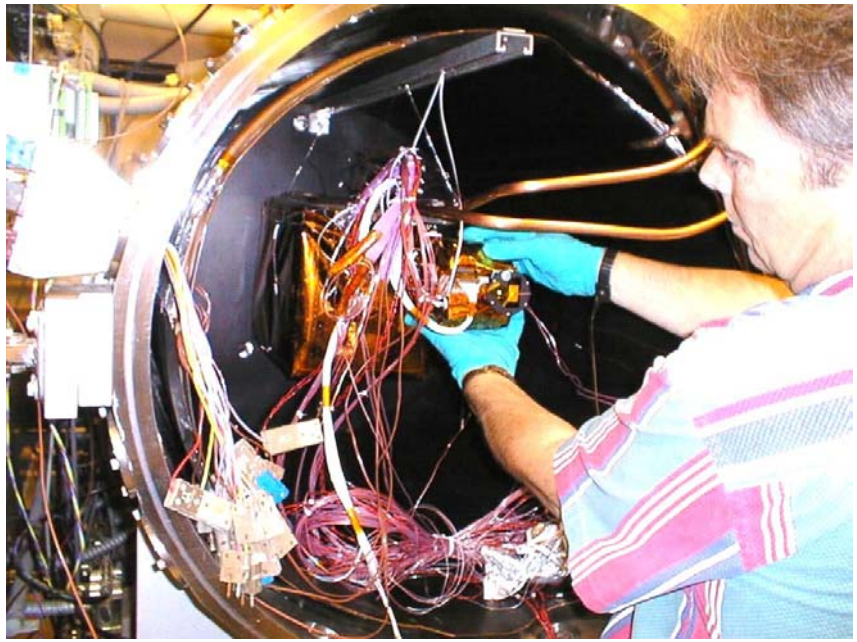
MER Propellant Line Thermal Blanket Development Test

- **Objective**
  - To characterize effective emittance for a series of blanket geometries
    - Straight
    - Tee
    - Elbow
- **Results were imported into analytical model for heater sizing**
  - Thermal balance for a propellant line zone is on the order of a few tenths of Watts



APEX Camera & Electronics Thermal Development Test

- **Objectives**
  - To determine amount of Mars nighttime survival heater power for the camera
  - To determine amount of camera warm-up heater power
  - To determine camera thermal response to transient changes in atmospheric & effective sky temperatures
  - To determine effectiveness of electronics thermal insulation
    - Novel approach that uses stagnant in-situ Mars atmosphere
  - To characterize electronics heat loses through insulation, mounting, and cabling



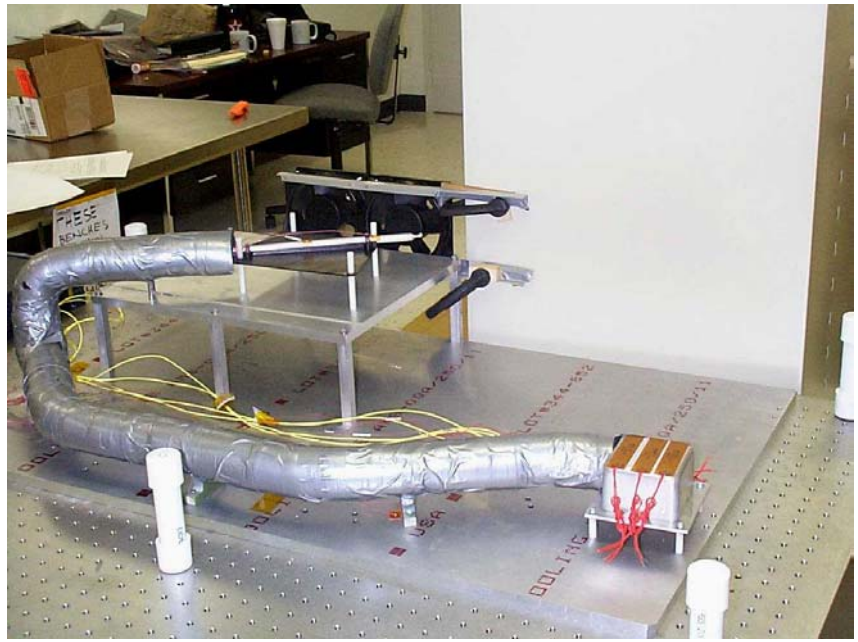
- **Results**
  - Adopted novel insulation approach as baseline
  - Verified survival & warm-up heater camera power
  - Correlated analytical model to transient test data

Assembly Protoflight/Qualification OR Flight Acceptance Testing

- Used to demonstrate assembly workmanship and design reliability
  - Sometimes referred as “margin testing”
- Test temperature levels, dwell times, temperature ramp rates, and number of thermal cycles are dictated by institutional or project policies
- Traditional test program is QUAL/FA or PF
  - EM hardware subjected to QUAL testing
  - FLT hardware subjected to FA testing
  - OR FLT hardware subjected to PF testing

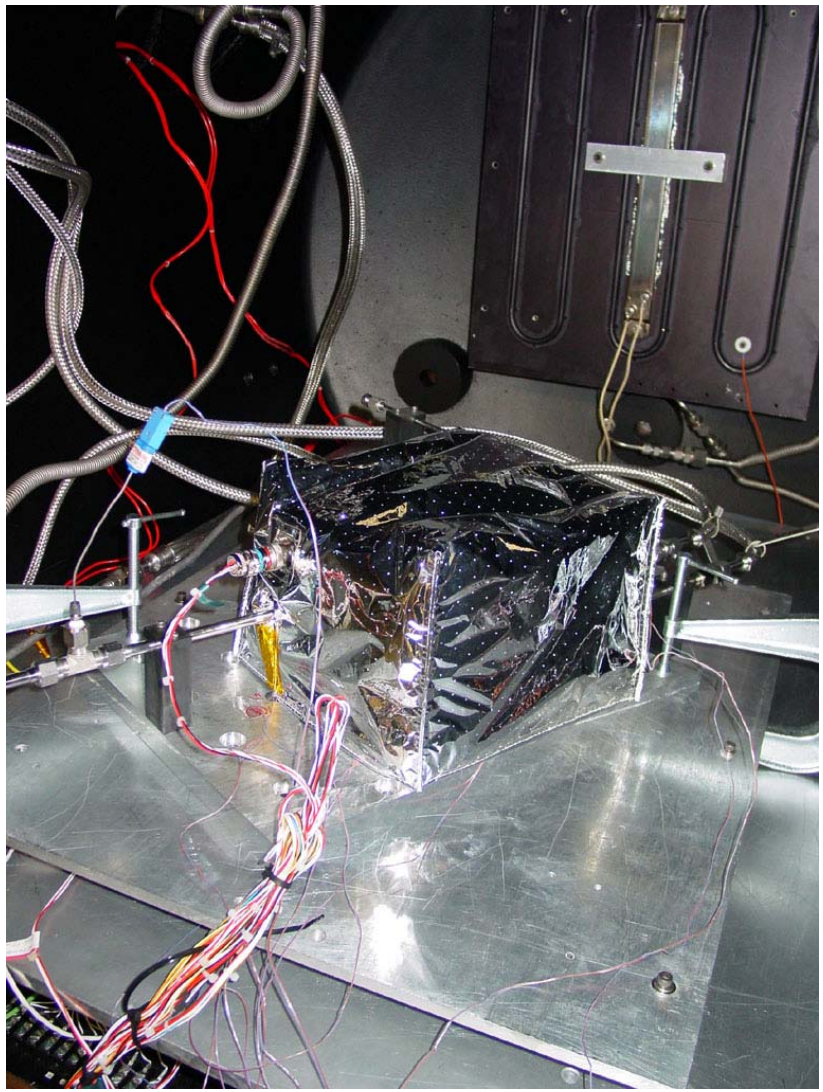
Mars'01 Lander Heat Pipe Flight Acceptance Test

- **Objectives**
  - Validate flight units function in reflux mode in-air
  - Validate capability to transfer 1 watt under various tilt angles
  -
  - Quantify thermal gradients along heat pipe
  - Compare pre-start-up thermal gradients to analytical predictions
- **Results demonstrated that flight units would transfer sufficient heat during cruise to Mars**
  - Hardware accepted for flight



MER Integrated Pump Assembly Thermal Protoflight Testing

- **Objective**
  - Demonstrate in-specification performance (pump ΔP & flow rate) over temperature ranges greater than allowable flight temperature (AFT) limits
  - Operating AFT limits
    - -20°C to +30°C
  - Operating Protoflight (PF) limits
    - -35°C to +50°C
  - Dwell durations
    - Cumulative 24 hours cold
    - Cumulative 50 hours hot
  - Number of thermal cycles
    - 3 times lifetime requirement
    - 3 test cycles
- **Test results met objectives**
  - Hardware accepted for flight



System- OR Assembly-Level Thermal Balance Testing

- **Used for thermal design validation and hardware functionality in expected thermal environment**
  - **"Validation" versus "Verification"**
  - **First discovery of a design deficiency is very costly (budget & schedule) to rectify at this point**
  - **Hardware functionality includes thermal items such as heaters, thermostats, temperature sensors, heat pipes/CPLs, & pumps**

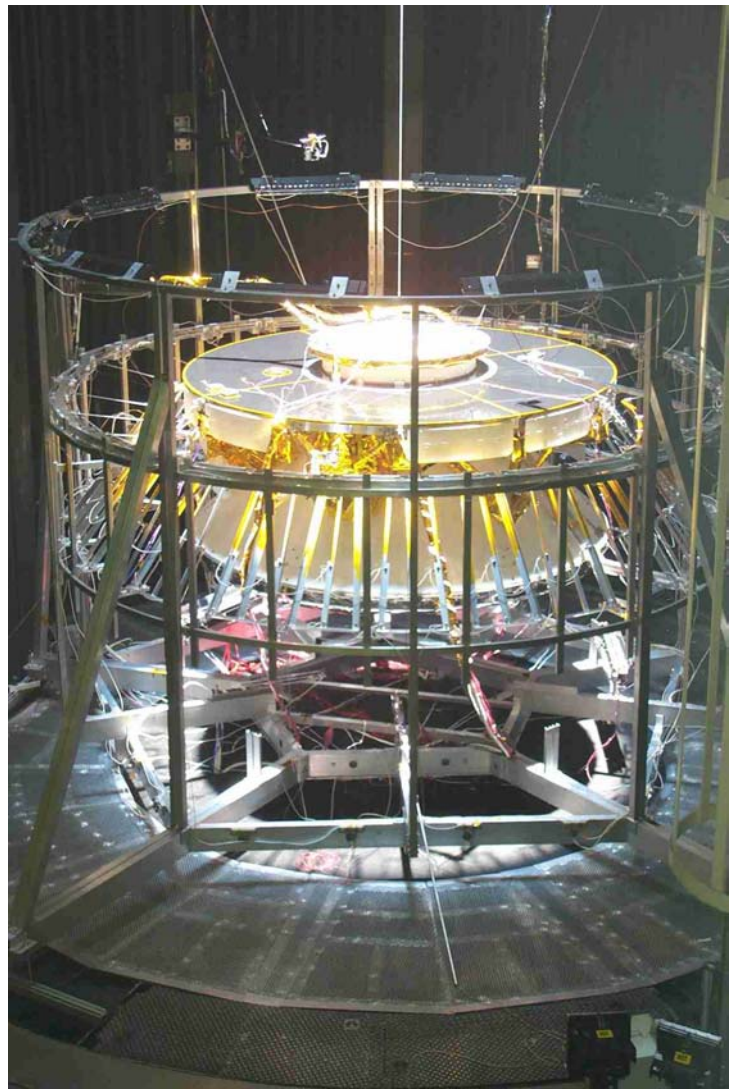
- **Two basic approaches**
  - **Empirical**
    - **Bounding worst-case thermal environments**
  - **Combination of test & analysis**
    - **Specified hot & cold thermal environment to obtain data for analytical model correlation**
    - **Analytical model utilized to demonstrate design requirement compliance**

GALEX Instrument Thermal Balance Testing

- **Objectives**
  - Validate instrument thermal design for worst-hot & -cold Earth orbit conditions
  - Validate survival (primary & secondary) heater string operation
  - Validate optical performance
- **Design validation was empirical**
  - Test results met objectives
    - Design maintained allowable flight temperatures for extreme environmental cases
    - Primary & secondary survival heater strings validated

MER Cruise Thermal Balance Testing

- **Objectives**
  - **Validate thermal design for mission worst-hot & -cold conditions**
    - **Solar simulation used**
    - **IR lamps used for off-sunpoint simulation**
  - **Validate mechanical pump fluid loop operation**
  - **Validate primary & secondary thermostatic heater strings**
- **Design validation was empirical**
  - **Test objectives met**
  - **Uncovered swapped primary & backup thermostats on four assemblies**
  - **Determined –Z sun sensor did not require silverized Teflon tape**



MER Mars Surface Thermal Balance Testing

- **Objectives**
  - To perform representative steady-state & transient cases to gather empirical data for analytical model correltation
    - Simulation of Mars surface environment extremely challenging (e.g., diurnal solar heating, wind simulation, 3/8 gravity field, CO_2 atmosphere)
  - To validate critical deployments & releases at cold temperature
  - To perform science instrument calibration at various temperatures
- **Design validation used a combination of test & analyses**

- **Results**
  - Test data confirmed development test results that WEB thermal design is robust
  - Provided empirical data for actuator heater warm-up validation
  - Demonstrated critical deployments & science calibrations